FOREST HEALTH PROTECTION
Pacific Southwest Region

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2007 Situation Summary

RED FIR DECLINE AND MORTALITY IN THE CALAVERAS RANGER DISTRICT, STANISLAUS NATIONAL FOREST

Since 2003, mortality of red fir in the northern district of the Stanislaus National Forest has become more pronounced and noticeable than in years past. Discussions involving forest leadership, district personnel, local private industry, and Forest Health Protection have been held to address the issue. Many questioned if this mortality was a continuing problem or a cyclic event. This report summarizes the current conditions of the general forest on the Calaveras and Summit Ranger District where most of the mortality has been detected, identifies insects and pathogens present, and discusses management alternatives that could be developed to mitigate the damage.

Surveys

During the summer of 2006, using 2004 and 2005 FHP aerial survey maps (*see* Appendix A), several large polygons were ground checked on the district delineated with mortality. Transects were run through areas in attempts to thoroughly capture stand attributes in which damage was occurring. Tree information on species, condition, diameter, probable year and cause of death were collected. Trees were not rated for dwarf mistletoe infection levels, but quick observations of stands easily showed moderate to severe infections at most locations. All locations visited were above 6000 feet in elevation, and predominantly composed of mature red fir. The average plot diameter-at-breast height ranged from 16 to 38 inches, with overall average of 24 inches; and basal areas varied between 180-250 square feet/acre.

Stand Composition

With the exception of a few plots, most of the live and dead basal area, and species composition was comprised of large-diameter red fir. Dead red firs were usually the largest trees in the plots, remaining as standing snags. Recent mortality of red fir was low – about one per plot, but older dead (more than 2 years dead, including snags) was nearly a quarter of the standing stems. Because of the low stem density per plot, the loss of one mature tree altered stand structure significantly. Three plots were mostly comprised of large-diameter lodgepole pine – one around Bear Valley Ski area, and two east of Sherman Acres; at the Tuolumne State Game Refuge, all

SOUTH SIERRA SHARED SERVICE AREA
USDA Forest Service, 19777 Greenley Road
Sonora, California 95370 (209) 532-3671

plots were predominantly large-diameter white fir with minor red fir component.

Ground observations were consistent with the FHP aerial detection maps 2002 to 2006 (*See* Appendix A). Since 2002, aerial surveyors detected very small areas of mortality (1 to 5 trees per acre) in the Calaveras and Summit Ranger Districts. By 2004, true fir damage was dramatically visible and widespread in both districts – most of which was *Cytospora* visible in tree crowns. In 2005, the largest mapped areas with mortality encompassed north and south of the Stanislaus River, by Big Meadow Campground on the Calaveras. Less damage was detected in 2006, again around and south of Bear Valley in the Calaveras RD.

INSECT/DISEASE AGENTS

Several damage agents were observed at all locations. Dwarf mistletoe infections were moderate to severe in most locations, indicating that infections have been present for a long time. Insects most often detected on recently dead firs were Flatheaded fir borer or fir engraver. Assessments of dead and live trees found that these agents are working as complexes that ultimately lead to tree decline. Much of the mortality observed was not the result of one damaging agent. (*See* Appendix B *for complete insect and disease biology*).

Dwarf mistletoe (*Arceuthobium abietinum f.sp. magnificae*) was the most prevalent damage agent observed on red fir. Witches' brooms were found in several large trees, indicating very old infections (*see* Figure 1). When trees are heavily infected, dwarf mistletoe will reduce diameter and height growth, ultimately resulting in mortality. Infections perpetuate when measures are not taken to mitigate spread or intensity of the disease. The parasitic nature of dwarf mistletoe is known to increase moisture stress and predispose hosts to attacks by fir engraver (Ferrell 1974, Berryman and Ferrell 1988) or pathogens – particularly *Cytospora abietis*.

Figure 1. Dwarf mistletoe broom in red fir (far right), leading to potential terminal breakage; Bear Valley Ski Area, Calaveras Ranger District.

Cytospora canker *(Cytospora abietis)* is a parasite that commonly attacks branches already infected by dwarf mistletoe. It is a canker-causing fungus that can kill young trees or treetops, where only branches are killed on larger hosts (Scharpf 1993). This pathogen is a normal component of true fir ecosystems. At certain locations on the Stanislaus National Forest, dwarf mistletoe and *C. abietis* infection in red fir is severe (*see* Figure 2). Dead branches are potential hazards for drivers and recreationists that frequent these areas. *Cytospora* infection levels at surveyed areas were moderate to severe, due in large part to the high levels of dwarf mistletoe already present. However, these infection levels were relatively low until about 2004, when there appeared to be a rapid increase of the pathogen throughout the crowns.

Figure 2. *Cytospora* infection on red fir, evidenced by red flagging; Aspen Meadow, Summit Ranger District.

Fir engraver (*Scolytus ventralis*) is the primary bark beetle found infesting the red and white firs on survey plots. Fir engraver attacks can be found scattered across the landscape, since they select hosts that are typically under severe stress due to lack of moisture or other debilitating condition. Outbreaks of fir engraver usually occur after periods of drought (Furniss and Carolin 1992). Based on studies developing risk-rating systems for red and white firs in Northern California, trees with ragged crowns and low live crown percentages were at highest risk for attack (Ferrell 1980). Primary causes of poor crown conditions were frequently attributed to prior dwarf mistletoe and *Cytospora* infection. Top-kill and terminal breakage by fir engraver then become potentially hazardous situations during heavy windstorms or wildfires.

Flatheaded fir borer (*Phaenops drummondi*) was found to a lesser degree on dead trees and again, in combination with heavy dwarf mistletoe, *Cytospora* infection, and fir engraver activity on trees.

No assessments of root disease were conducted as part of these surveys or in past examinations of these areas. In discussion with the service area pathologist (John Pronos, retired, *personal communication*), the possibility of annosum root disease is high in true fir areas that were historically logged or frequently disturbed. True firs are more vulnerable to infection than pines

and some of the tree decline occurring in the northern Stanislaus is found to be associated with root disease presence.

DISCUSSION

Preliminary ground surveys and recent aerial detection reports find that much of the red fir deterioration in the Calaveras and Summit Ranger Districts are due to a number of interacting "stressing" factors that gradually result in tree mortality. Old age, stand structure, and dwarf mistletoe are the primary predisposing factors that initiate decline. As trees continue to grow, the prolonged presence of dwarf mistletoe slowly reduces host resistance and vigor. Crowded stand conditions contribute to widespread mistletoe distribution in neighboring hosts. The largest trees in surveyed areas were unfortunately those with the heaviest mistletoe infection. However, mistletoe infection alone can take years to directly kill trees. Severe drought years during 2002-2005 (Forest Health Highlights 2006) most likely aggravated moisture stress on infected host trees, inciting insect attack and other pathogen infection. While their prevalence was ubiquitous in observed trees, bark beetles and *Cytospora* are merely contributing factors to the eventual decline of the red fir.

No Action

If stand conditions in red fir infected areas are not altered from their current state, insect and disease associated injury will continue and possibly even increase. Eventual mortality, branch dieback, and top-kill of red fir by dwarf mistletoe and bark beetles can be expected. Understory regeneration will die from infection or become infection sources as they develop. Uneven aged stands will not outgrow existing dwarf mistletoe infections as the mistletoe is continually cycled in all age classes. As infection intensifies, host growth is reduced, *Cytospora* infection courts and susceptibility to bark beetles increases. Mortality levels may fluctuate from year to year, but over time will be higher than normal. During periods of drought, heavily infected trees will be unable to withstand the additional stress and succumb.

A 'hands-off' approach toward infected red fir stands has multiple effects besides tree loss. Seed sources in the form of overstory trees are eventually lost from prolonged mistletoe infection or insect attack. The build-up of dead trees – standing or downed – create dangerous fuel conditions in the event of wildfire. Such high fuel loads typically result in stand-replacing fires that completely destroy all vegetation and may require intensive management to recover. Personal property adjacent to Forest Service lands should be considered in areas where infected red fir trees pose a risk.

While dwarf mistletoe infections and bark beetle associated mortality are typically viewed as losses, they can be indirectly beneficial to other components of the ecosystem. From a wildlife management standpoint, the effects of mortality agents in a stand can be positive. Snags, downed woody material, and dead tops created by insects and pathogens may be desirable. Bark beetles and mistletoe help create openings in the stand that benefit wildlife and increase structural and species diversity. Bark beetles, dwarf and leafy mistletoe plants and fruits are common food sources for other insects, birds, and mammals. Witches' brooms may provide cover and nesting sites for many wildlife species.

Management Treatment Options and Considerations

While several factors have been presented as causes for decline, the only manageable factors are stand structure and dwarf mistletoe. Fir engraver and flatheaded fir borer populations are currently not at epidemic levels, and thereby should not be bothered with at this time. Prevention of *Cytospora* infection is also unfeasible as spores are wind disseminated. Climate change to warmer summer temperatures, less winter precipitation could result in sustained drought, but also cannot be controlled nor accurately predicted. Therefore, dwarf mistletoe management should be the focus of planning efforts for improving overall forest health. Changes in stand structure will result as dwarf mistletoe mitigation is implemented. These options can easily be integrated to support other resource objectives as well.

Depending on the current state of the stand, rigorous treatments may be necessary to bring stands to a manageable level. "Manageable" levels of DM are low mistletoe incidence and negligible growth losses.

Under the category of Old Forest Ecosystems in the Sierra Nevada Forest Plan (2004), tree removal is restricted above 25 inches or that 40% basal area of the largest trees will be retained, except in the case of fuel treatments. The irony is that many of the largest trees had the highest ratings of infection in the stands surveyed on the Stanislaus National Forest. Surveys found that while overall stand average was 24 inches DBH, red fir as major overstory averaged up to 31 inches DBH. Some firs were as large as 49 inches in diameter with few stems per acre. Despite good intentions of the SNFP, the regulations constrain efforts to develop healthy old-growth stands. Leaving infected large diameter trees will only perpetuate the cycle of infection and resulting unwanted mortality in all age classes from contributing insect and pathogens. Therefore, desired future objectives for a healthy, resilient forest may be compromised if adequate management is not implemented.

The ultimate goal of treatments should be to minimize infection spread and intensification of dwarf mistletoe (Parmeter 1978). Outlined are treatments that require whole tree removal, tree/stand manipulation, or complete clearing to create buffer strips. Mistletoe infection levels at particular locations may necessitate removal of large trees to prevent re-infection of the understory. Following are management treatment options suggested for use to treat dwarf mistletoe-infected red fir stands.

Direct

1. **Broom Pruning**

   Objective: To extend tree life and maintain individual treated trees on a site as long as possible.

   Guidelines: Remove dwarf mistletoe witches' brooms from high-value trees only if they will have at least 30% live crown after removal of the brooms. This treatment will not eliminate mistletoe from the stand, nor will it prevent future spread. It is most often used in areas that have little or no understory.

2. **Tree Removal**

   Objective: To remove trees expected to die within ten to fifteen years, to prevent build-up of bark beetles, and to reduce dwarf mistletoe in the stand.

Guidelines: Identify and remove trees with a Dwarf Mistletoe Rating[1] (DMR) of 5 or 6, or a rating of 4 with mistletoe in the upper one-third of the crown. Such trees are generally not prunable, pose a threat to adjacent uninfected hosts, and have a higher probability of dying within 10-15 years or during the next drought. It is advisable to remove infected firs that will have less than 30 percent live crown after pruning, or are growing in dense aggregations where removal of selected individuals would benefit neighboring uninfected or slightly infected firs. Remove all trees having bole infections at a point less than six inches in diameter. Bole infections are not serious from the standpoint of spreading mistletoe, but they deform and/or lead to mortality of small trees and failure of large trees.

3. Creation of Buffer Strips

Objective: To limit or stop the spread of dwarf mistletoe into a treated area from adjacent infested areas.

Guidelines: Use host-free strips to prevent mistletoe from re-entering the control area or where the parasite is not eliminated, from leaving the site. Buffer strips should be at least as wide as the height of the highest mistletoe plants in the adjacent infested stand. Examples of existing buffers include meadows, roads, rivers, clearings, and aggregations or plantings of non-host trees. Construction of new roads, structures, or campsites can also be used to create buffer zones and eliminate pockets of heavily infected trees.

4. Branch Pruning/Eradication

Objective: To reduce or eliminate dwarf mistletoe seed in the stand and improve tree vigor.

Guidelines: For trees with DMR of 3 or less, or a rating of 4 and no mistletoe in the upper one-third of the crown, prune all lower branches, both healthy and diseased, at the bole up to including the second whorl of branches above the highest visible mistletoe infection. Experience has shown that despite removing branches up through the highest infection or even one more whorl, latent infections almost certainly appear in three to five years. Whenever possible, avoid removing more than 50% of a tree's live crown. Pruning of all infected branches in infected trees in an attempt to eradicate this pest requires careful adherence to these guidelines, and will have the greatest chance of success when used on isolated high-value trees or in areas of one acre or less where infection is light. Do not attempt eradication if the pruning will result in a tree with a crown of less than 30%, or if the tree will be exposed to continued infection from adjacent infected trees. It is difficult to completely eliminate dwarf mistletoe from a tree without at least two treatments. Plan to reenter if needed at least twice after the first entry.

Indirect

1. Thinning

[1] Hawksworth, F.G. 1977. The 6-class mistletoe rating system. General Technical Report RM-48. Rocky Mountain Forest Range and Experiment Station, Fort Collins, CO. 7 pg.

Objective: To improve stand growth and tree vigor.

Rationale: Despite direct dwarf mistletoe treatment, the benefits from reducing or eliminating infection may be offset by continuing competition for growing space in overcrowded stands. When stands are overstocked, mistletoe vertical spread is increased due to crown thinning and reduced height growth (Parmeter 1978). Even where mistletoe is absent, overstocking contributes to poor tree vigor and unnecessarily high risk of death from bark beetle attack. Although privacy and esthetic requirements in campgrounds may prevent thinning to stocking levels optimum for timber-producing forests, some thinning may be necessary if campground stands are to maintain vigor and resistant to pest attack.

2. **Favoring and Planting Non-hosts Conifers and hardwoods**

Objective: To eventually replace infected trees with uninfected trees and to lessen future spread of dwarf mistletoe.

Rationale: Because true fir dwarf mistletoe infects neither pines or hardwoods, managers may favor these non-hosts so that they become a larger component of the stand. Selected individuals or small aggregations of these non-host species may be retained as buffers to movement of the parasite, or as eventual replacements for severely infected firs that cannot be removed during mistletoe treatment. Wherever there are pure stands of severely infected hosts, planting of non-susceptible species may be the only way to ensure that new trees replace the firs that die or are removed.

Direct suppression efforts to control fir engraver or flatheaded fir borer are not advisable if the residual stand is still susceptible to attack. Resurgence can occur if treatments do not address improving overall stand condition. Management actions that target other resource objectives such as fuel reduction or wildlife habitat preservation in these red fir communities can incorporate strategies that also attend to insect and disease issues.

Some management options may not feasible due to size of treatment areas, funding, accessibility, etc., but proper application of treatments in strategically placed or high priority areas would still be valuable in improving current stand conditions. Pruning of mistletoe-infected branches are effective in rejuvenating tree vigor while reducing the spread of infection onto regenerating understory. If there is no susceptible understory to protect, low dwarf mistletoe infections in the overstory can be tolerated. Whole tree removal of highly infected individuals would also be a step towards long-term prevention. If management is considered, procedures must be properly implemented to not further aggravate or promote subsequent insect/disease infection, repeated treatments may be necessary. Complete eradication of dwarf mistletoe would not be practical or feasible at these levels of infection. At a minimum, dwarf mistletoe infections should be used as a factor in identifying trees that should be removed eventually. The best approach would be to eliminate or reduce dwarf mistletoe to insignificant levels since stands can tolerate low infection ratings and continue to be very productive.

Growth and Mortality Data: The tables below show how dwarf mistletoe affect true firs. This data is taken from Hawksworth, F.G. et al., “Interim dwarf mistletoe impact modeling

system: User's guide and reference manual." USDA Forest Service, Methods Application Group, Fort Collins, CO. Report MAG-91-3, March 1992. 90 pg.

Table 1. Relationship of True fir Diameter growth potential to Dwarf Mistletoe Rating (DMR)

DMR	**0**	**1**	**2**	**3**	**4**	**5**	**6**
10-year diameter growth potential (%)	100	100	100	98	95	70	50

Table 2. True Fir 10-Year Mortality Percentages

DMR	**0**	**1**	**2**	**3**	**4**	**5**	**6**
% mortality, small trees (DBH < 9 inches)	0.0	0.8	2.8	6.1	10.5	16.2	23.1
% mortality, large trees (DBH > 9 inches)	0.0	0.7	2.3	5.0	8.8	13.5	19.2

While the survey locations presented here are but a small percentage of the Forest where red fir occurs, they represent areas of sizable and significant value and use. Protection of these areas and others should concern more than just local forest managers and immediate community residents. More surveys of red fir forests in the Stanislaus are planned in the upcoming years. If you have any questions or require more information, please do not hesitate to contact our field office.

/s/ *Beverly M. Bulaon*
Beverly M. Bulaon
South Sierra Shared Service Area

CC: Bill Lorenz, John Schmechel, Deb Romberger, Tom Quinn, Martin Mackenzie

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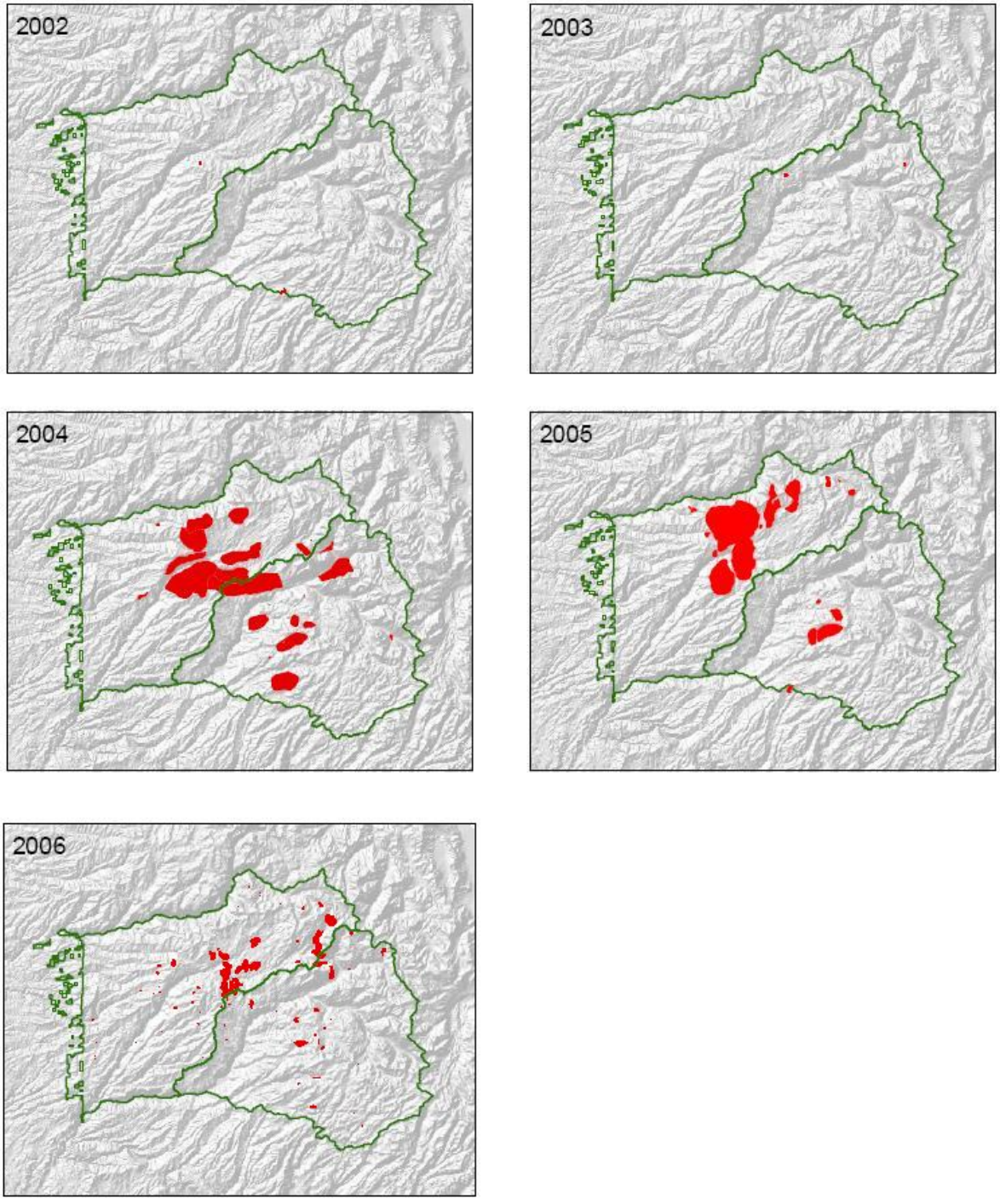
Appendix A. 2002-2006 Forest Health Protection Aerial Detection Surveys of True Fir in the Calaveras and Summit Ranger Districts, Stanislaus National Forest.



Appendix B: Insect and Disease Biology

Dwarf mistletoe (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts. True Fir dwarf mistletoe (*Arceuthobium abietinum*) infects principally red fir (*Arceuthobium abietinum f.sp. magnificae)* and white fir (*Arceuthobium abietinum f.sp.abietinum*).

Dwarf mistletoe spread by means of seed. In the fall, the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20-60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long-distance spread of dwarf mistletoe are occasionally vectored by birds and animals. Vertical spread of mistletoe within true fir crowns is normally limited to less than one foot per year because of foliage density.

Dwarf mistletoe are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole-swellings.

Cytospora abietis is a canker-causing fungus that infects true firs throughout their range in California. It is a weak parasite, and usually attacks trees that have been weakened by disease, drought, fire, insects, or human disturbance. It is most commonly associated with dwarf mistletoe infection, and sometimes attacks as many as a quarter of the mistletoe-bearing branches, killing many each year. The bright red flags of recently killed branches on dwarf mistletoe-infected red firs are almost always the result of lethal *Cytospora* infections. *C. abietis* occasionally reaches especially damaging proportions in certain years, and may attack trees of any age, sometimes killing the tops or all of young trees.

The Fir engraver (*Scolytus ventralis*) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in the firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, adults overwinter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper

bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after beetles have emerged.

Abstract

The mortality of red fir in the higher elevation forests of the Calaveras Ranger District, Stanislaus National Forest has generated a considerable amount of concern and interest. Ground surveys were conducted in 2006 in several areas on the district to assess insect and disease presence. The purpose of the surveys and following report were to identify damage agents and stand conditions that may be causing much of the decline. General management alternatives are outlined in the conclusion for consideration.